ENERGY EXPENDITURE BY MAN

It is notorious that there are fashions in science. The discovery of a new approach in any branch of work tends to direct attention to a restricted aspect: not until the cream has been skimmed by means of the new technique is a balance restored. The study of nutrition is peculiarly liable to such tendencies: the discovery of vitamins ushered in a fruitful and major preoccupation with the fundamental biochemical processes of cellular metabolism, and so did the appreciation of the importance of trace elements. Indeed, the earlier interest in 'proximate principles' was well-nigh ousted, and the dictum, "look after the calories in food and the other constituents will look after themselves", fell into a probably well-deserved disrepute.

In nutrition, however, there is a very special sense in which a balance of interest must be preserved. As individuals and as communities we must balance the intake and expenditure of energy: the energy we give to the world in the work of our muscles and in the heat of our bodies we must recapture from food. If expenditure exceeds income, the body of the individual wastes away, and on a national scale famine is abroad in the land; if intake is greater than expenditure, the individual will suffer from the lethal nuisance of obesity, and in the community there will be a glut and, in default of adequate methods of storage, a waste of food. Thus it is not sufficient to concern ourselves solely with the intake of food, to make available what we believe to be a safe margin in excess of requirements. If it comes to the point that we have to adjust our expenditure to income, we shall have to know how best to use the energy available to us. To combat obesity, the usual practice is to recommend a restriction in intake of food. But a human being is not a mere machine. He has genetical roots stretching far into the past when his body was adjusted to a life of hard physical toil. To restrict the intake of food is to throw his physiological processes out of gear, and it is better, if the food is available, to adjust the balance by increasing exercise. That demands some knowledge of the time-course of energy expenditure in different activities.

At the beginning of this century there was considerable interest in human calorimetry, both direct and indirect, this interest being well illustrated in the successive editions of Graham Lusk's classical book "The Elements of the Science of Nutrition" (1906–31). For the reasons already mentioned, interest in calorimetry lapsed but now shows signs of a revival, in part due to the introduction of new apparatus and in part due to a realization that, after all, calories do matter. It was not inappropriate, therefore, that the Nutrition Society should arrange this year a symposium on the "Energy Expenditure by Man", which was held in the National Institute for Medical Research, Mill Hill, on October 15.

The first paper at the symposium, on the development of experimental methods for determining the expenditure of energy by man, was given by C. G. Douglas. He explained briefly the theoretical bases of calorimetry and followed the changes in technique, primarily in indirect calorimetry, from the early days of Regnault and Reiset[1] in 1849 to the present time. There have been no changes in fundamental principles and surprisingly few variants in the technical approach to the problem. The determination of the expenditure of energy depends on measurement of the gaseous exchange between a living organism and the atmosphere which surrounds it. The earlier techniques tended to be elaborate and cumbrous. The animal or human being was enclosed in a chamber through which air was circulated by a pump. The oxygen used by the animal was replaced from outside the system, and carbon dioxide absorbed within the system. Such techniques restricted gravely the living activities which could be studied, although brave attempts were made to study muscular activity in man by placing ergometers within large chambers. Indirect calorimetry was first successfully freed from the shackles of cumbrous laboratory equipment by Dr. Douglas's use of a large gas-tight bag to collect the expired air. Such a bag could be worn on the back, giving the subject very considerable freedom to carry out normal activities. The idea came to Dr. Douglas when watching an old-fashioned 'magic lantern': the gases for the lime-light were stored in large bags. No advance on this Douglas-bag technique appeared until 1940, when German workers introduced the Kofranyi–Michaelis respirometer (Max-Planck respirometer), which is a reversion to an old principle[2]. The expired air is passed through a light, dry flowmeter worn on the back like a haversack. As the expired air passes through the meter, small samples are withdrawn and collected for subsequent analysis.

Accurate methods of indirect calorimetry demand accurate gas analysis. Attempts have recently been made to replace the Haldane and similar types of apparatus by rapid physical methods; but these have not yet proved satisfactory.

H. S. Wolff described his light-weight integrating motor pneumotachograph[3], the principle of which is the same as that of the Max-Planck respirometer, except that the flowmeter employs a method new to calorimetry. The pressure of the expired air lifts a diaphragm from off the exit tube of the meter, and the lift of this diaphragm is proportional to the flow. The excursion of the diaphragm, by means of an electro-mechanical integrating device, allows the volume of expired air to be read on a veeder counter. In the latest models the volume of air expired can be recorded at a distance by transmitting impulses from the meter. A small pump draws a sample of expired air into a polythene bag, and the air in this bag is afterwards analysed. The pneumotachograph, with its associated equipment, is light, offers little back pressure to breathing and records faithfully rates of flow far in excess of those found during maximum expiration in strenuous exercise: with a face mask it can be worn for hours without distress, and thirst can be slaked with the mask in position. Observations have been made on men in the Army performing hard physical exercises. The way is thus open for a very complete survey of the expenditure of energy over long periods and in all walks of life.

In the afternoon session O. G. Edholm dealt with the value of measuring expenditure of energy in nutritional studies. These in the past have depended almost wholly on dietary surveys. Such surveys give reasonably accurate information on the income of energy, but give no indication of how the energy is spent. A review of the few surveys in which both intake and expenditure were measured shows good agreement on the average over a period of days. In a recent careful study[4], however, no correlation was found between individual daily intake and expenditure of calories: there was no correlation even between the mean expenditure of the group on any one day and the intake on that day. There was a correlation between the mean expenditure on one day and the intake two days later. Here is revealed an aspect of metabolism that is but imperfectly understood. The human body is able apparently to adjust its intake of food to an expenditure of energy which took place days before. Indeed, there is evidence that such belated adjustment may extend over a much longer period.

R. Passmore discussed the time-course of the daily expenditure of energy by human beings. With increasing mechanization in industry, with '*Homo sapiens*' becoming '*Homo sedentarius*', we tend, in our estimation of the severity of work, to place undue emphasis on the nature of the employment. Lying, sitting and standing occupy a large part of the twenty-four hours even for an active man. Roughly 500 Calories are spent asleep in bed, and 1,500 Calories in recreation and off-duty activities; and this seems to hold whether the occupation involves light or heavy work. Should there be a diminution in expenditure of energy in the period of recreation, as there may well be with advancing years, and if the appetite is not correspondingly curbed, obesity will rear its ugly head.

J. V. G. A. Durnin had the rather thankless task of talking about the influence of age on expenditure of energy. The report on calorie requirements by a committee of the United Nations Food and Agriculture Organization[5] suggests that the intake of calories at twenty-five years of age should be decreased by 7·5 per cent for every ten years beyond that age. There is very considerable criticism of this proposal; but the original suggestion, and all criticisms thereof, suffer alike from a practically complete lack of known facts. Information is badly needed in all communities where shortened working-hours for the young make an increasing demand for labour from the elderly. How do advancing years affect muscular efficiency, and what load can we place with safety on the age group 55–70 years? We do not know. A short pilot experiment showed that elderly men used more energy in walking than did younger men. The elderly, however, spent no more energy when the exercises were confined to the muscles of the arms. There is no reason why the metabolic processes in the muscles of the elderly should not be as efficient as those in younger people; perhaps neuromuscular control is not so efficient.

H. R. Noltie dealt with the expenditure of energy by athletes, a subject on which information is scanty: with the older techniques it was scarcely feasible to find with any degree of accuracy the expenditure of energy during the more strenuous and competitive forms of exercise. Golf is known to make comparatively modest demands on expenditure of energy, about 5 Cal./min.; fast walking, due to swinging of the arms, can be expensive in energy and even more expensive than slow running: sustained running at speed may demand 25 Cal./min. Swimming makes very great demands, and so does skiing. But the ski, from the point of view of energy expenditure, is, in all circumstances, more economical than the snowshoe. It is possible, too, to estimate the influence of style and of length of stride in running. The 'fast start' is costly in terms of energy expenditure. Thus, it is not beyond the bounds of possibility that athletes, trainers, and spectators with a financial interest in the outcome will all have ultimately to discuss athletic contests in relatively pure physiological terms.

General discussion after the final paper tended to focus on obesity, on its causation and on the very real problem of the control of body-weight: restrict the food intake and we are unhappy, increase exercise and we become all the hungrier. What is the cause of fatigue? What causes muscle soreness after unwonted severe exercise? We have no answers. These may come by future closer integration than in the past between the physiological and biochemical approaches to the problems of nutrition.

[1] Regnault, V., and Reiset, J., *Ann. Chim. (Phys.)*, **26**, 299 (1849).
[2] Kofranyi, E., and Michaelis, H. F., *Arbeitsphysiologie*, **11**, 148 (1940).
[3] Fletcher, J. G., and Wolff, H. S., *J. Physiol.*, **123**, 67*P* (1954).
[4] Edholm, O. G., Fletcher, J. G., Widdowson, Elsie M., and McCance, R. A., *Brit. J. Nutr.*, **9**, 286 (1955).
[5] "Calorie Requirements" (Washington, D.C.: F.A.O., 1950).

OBITUARIES

Dr. W. K. Spencer, F.R.S.

Dr. William Kingdon Spencer, whose death occurred at Ipswich on October 1 at the age of seventy-six, was a prominent figure in the world of education who, notwithstanding exacting official duties, found time to carry out important researches on fossil starfishes and other Echinodermata. The son of J. F. Spencer, formerly of Parkstone, Dorset, he was born at Barrow-on-Soar, and spent his boyhood at Upper Hopton, Yorkshire, where his father had been appointed headmaster of the village school. From Batley Grammar School (where he was a contemporary of Sir Owen Richardson) he gained a demyship in natural science at Magdalen College, Oxford, where he proceeded in 1898 after studying for a short time at the University of Marburg. Graduating in 1902 with first-class honours in zoology, he was awarded the Burdett-Coutts Scholarship and began his researches on fossil invertebrates.

For a year (1903–4) Spencer held the post of lecturer and demonstrator in the University Department of Geology at Oxford, under W. J. Sollas. His career as a teacher of palæontology soon terminated, however, for in 1904 he was appointed to a post under the Board of Education, and before long became the Board's chief examiner in science. In 1914 he was appointed inspector of schools for East Suffolk, where he guided the educational programme until his retirement in 1938 and was largely responsible for the very effective reorganization and the extension of the schools of that area which followed the Hadow Report of 1926. On retirement he lived for a time in southern France and continued with his research work in the University of Montpelier. When France was overrun by the German army he escaped to Portugal and proceeded to South Africa, where he resumed educational work. After the War he again retired to France, first re-visiting Great Britain in 1953.

Spencer's first echinoderm paper, published by the Royal Society in 1904, dealt with the Palæozoic genera *Palaeodiscus* and *Agelacrinus*, to the investigation of which he applied Sollas's technique of serial sections.